CLIMATE RISK AND FARMING SYSTEMS IN RURAL CAMEROON

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Abstract

Climate risk is particularly burdensome to small-scale farmers in developing countries due to heavy dependence on natural resources, limited and erratic rainfall with high inter- and intra-annual variability, and other natural calamities. Numerous studies on climate change suggest that climate variability is expected to increase in the next few decades, and that it is likely to be severe for tropical areas. For the design of better intervention strategies that are capable to stabilize the incomes of the poor and decrease vulnerability, it is mandatory to have a good understanding of the livelihoods of rural populations, and the risks they are facing.

This paper presents an approach to measuring climate risk and its impact on livelihood outcomes in fishery-dependent communities in the *yaéres* floodplain (Far North Province of Cameroon) by applying portfolio theory and stochastic dominance rules. The focus of the analysis is put on the question, how portfolio decisions of households affect income and risk in different production systems. Assuming possible future scenarios we can derive approximate predictions of the effects of climate change and rural development interventions on income and the "riskiness" of different activity portfolios. The results suggest that the diversification effect in the study area is limited due to high correlation of income flows from different activities. However, we show that development intervention strategies, which particularly aim at changing the covariation structure of income flows, are most successful in reducing risk, and potentially increasing income.

Keywords: Climate risk, agricultural diversification, portfolio theory, Sub Saharan Africa

JEL Classification: G11, Q12, Q54

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1 Introduction

Because the effectiveness of rainfall for crop and fish production is a function of the temperature values which affect evaporation and transpiration, climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors, for example the soil's moisture and fertility. Adverse climate effects can influence farming outputs at any stage from cultivation through the final harvest. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops (Ellis 1993, Molua and Lambi 2006). McCarl et al. (2008), for example, have shown that precipitation intensity (i.e. periods with high amounts of rain while the rest of the year is relatively dry) and droughts in US agriculture are harmful for the crops and are of greater concern than the annual amount of precipitation alone. Although the adverse effects of these hazards on agricultural output are prevalent in most parts of the world, they are particularly burdensome to small-scale farmers in developing countries (Hazell and Norton 1986, Reilly 1995, Smith and Skinner 2002, Tingem and Rivington 2009, IFAD 2008). Ellis (1993) and Dercon (2002) point out that production uncertainty is pervasive and serious for these households due to the unpredictable nature of climatic conditions. In combination with prevailing poverty the outcome of uncertain events makes households vulnerable to serious hardships and may make a difference between survival and starvation.

Farming systems in the Sudano-Sahelian zone of Sub-Saharan Africa are predominantly vulnerable to natural hazards, as they are often subject to heavy dependence on natural resources, limited and erratic rainfall with high inter- and intra-annual variability, pests and diseases, nutrient-poor soils and other natural calamities (Ellis 1993, Hardacker et al 1997, Townsend 1994, Kinsey et al. 1998, Affognon 2006, Dercon 2002). A study on vulnerability to climate risk in Africa by Thornton et al. (2008), for example, identifies mixed rainfed arid-semiarid systems in the Sahel as the highest vulnerable region with possibly severe LGP (length of the growing period) losses. For the rural population in this zone, whose main sources of livelihood are agriculture and fishing, the unpredictable climate has a more severe impact on the poor than for the better-off households, reinforcing social differentiation and holding a bleak prospect for agricultural production (Ellis 1993, Molua and Lambi 2006). Numerous studies on climate change suggest that climate variability is expected to increase in the next few decades, and that it is likely to be severe for tropical areas. Extreme events, such as floods and droughts will increase in frequency, thus increasing the probability of income shocks having a larger impact on the poor (Kurukulasuriya and Mendelsohn 2008, Iwasaki et al. 2009, Shewmake 2008, Slater et al. 2007, Tingem and Rivington 2009). Molua (2006) and Molua and Lambi (2006) observe that estimates based on climate data from Cameroon (1961 to 2001) indicate pronounced seasonality. Rainy seasons have become wetter and dry periods dryer. Based on a comprehensive survey across 11 African countries, Hassan and Nhemachena (2008) report that over 50 percent of farmers perceive an increase in temperature and a decline in annual precipitation.

Although most farmers have traditional knowledge of rainfall patterns (e.g. interpreting the height of an ant nest in trees, or the color of frogs to make forecasts on the onset and cessation of the rainy season and quality of rain (Molua 2006), they are often surprised by changes in the 'normal' rainfall patterns, particularly if a run of wet years is followed by one of dry years. However, decision-making choices on the allocation of land, capital and labor can often hardly be altered during the cropping period as a response to climate conditions. Also, climate predictions by use of models are unlikely to be able to project climate changes due to many unknown parameters such as the time of onset of seasonal rainfall and the prevalence of dry spells within seasons (Slater et al. 2007). Coping with risk, farmers have therefore to consider production uncertainty ex-ante in making decisions on their activities portfolio (Barrett et al. 2001, Di Falco and Chavas 2009). Numerous empirical studies have shown that farmers behave in a risk-averse way (see Ellis 1993). As such, profit maximization is not the guiding principle for these households. Instead, rural households typically pursue the overall goal of utility maximization (Brown et al. 2006, Norman et al. 1995). Under the weak assumptions of rational behavior and risk aversion, maximizing utility is often equalized to achieving an optimal combination of mean income and risk. A central proposition in applied economics is that optimal diversification through combining activities with low positive covariance and income-skewing (reducing the risk of the overall return by selecting a mixture of activities whose net returns have a low or negative correlation) is a primary risk reducing strategy (e.g. Di Falco and Chavas 2009, Just and Pope 2003, Dunn 1997, Thomas et al. 1972). In other words, farmers spread risk by diversifying the allocation of productive assets among various income-generating activities, often preferring farm plans that provide a satisfactory level of security even if this means sacrificing income on average (Ellis 1993, Crole-Rees 2002). Empirical studies on farmers' motivation to diversify the activity portfolio also suggest that the motivation to reduce uncertainty and risk ranks first among other possible motives (e.g. Barbieri and Mahoney 2009). Repeatedly, recommendations for policymakers therefore stress the need to support diversification to reduce rural poverty and help farmers to cope with increased uncertainty about possible futures (see Slater et al. 2007, CGIAR 2005, IFAD 2008, Tingem and Rivington 2009, Molua and Lambi 2006).

In assisting policymakers to design better intervention strategies that are capable to stabilize the incomes of the poor and decrease vulnerability, it is mandatory to have a good understanding of the livelihoods of rural populations, and the risks they are facing. Although macro-level studies on climate risk and nation-wide yield forecasts are an important instrument to raise awareness of the coming risks, there is a need for higher-resolution system studies, which can suggest development interventions adapted to local needs and conditions. Thornton et al. (2008) argue strongly "against large 'magic bullet' approaches, and in favor of smaller, better targeted local approaches and interventions" (p.41). Reidsma et al. (2009) point out that in order to project impacts of future climate change on agriculture, current farm management strategies as well as their influence on current production need to be considered.

This paper presents an approach to measuring climate risk and its impact on livelihood outcomes in fishery-dependent communities in the *yaéres* floodplain (Far North Province of Cameroon). A visual impact method (Hardacker et al. 1977, Anderson et al. 1977) has been used to collect data on risk in agricultural and fisheries production for a representative sample of 238 households. As analytical instruments we apply the portfolio theory (Markowitz 1952) and stochastic dominance rules. The focus of the analysis is put on the question, how portfolio decisions of households affect income and risk in different production systems. This approach allows the identification of the relative role of different livelihood activities in the income portfolio. Assuming possible future scenarios we can derive approximate predictions of the effects of climate change and rural development interventions on income and the riskiness of different activity portfolios, and draw useful conclusions for policy makers with regard to sustainable rural development and poverty alleviation in Sub-Saharan Africa.

2 Approaches to risk and diversification

Empirical studies on diversification and risk can be broadly divided into two fields. One approach focuses on the analysis of cross-section or panel household data, investigating the effects of diversification on mean income or the inequality of income distribution by use of econometric models. These approaches allow the identification of the contribution of, for example, farm or off-farm activities to overall increases in income (e.g. Reardon et al. 1992, Crole-Rees 2002). A second strand of literature is explicitly dealing with risk, employing a wide variety of formal risk analysis instruments that have been developed in the last decades in order to come up with effective risk-management strategies for farmers. Such farm planning models that are designed to find an optimal combination of farming activities of a "typical farm" are based on the portfolio theory, which has its analytical foundation in Von Neumann and Morgenstern's expected utility theory under uncertainty. Attention in agricultural economics has especially concentrated on optimization methods with mathematical programming techniques (and linear capital and technical constraints) to model farm decision problems and to find the portfolio of farming activities which maximizes expected utility (EU) under risk.

Among others these comprehend the application of expected utility theory on the treatment of optimal farm plans by use of the mean-variance (E-V) criterion with quadratic programming models (Markowitz 1959, Tew et al. 1992, Scott and Baker 1972). The solution of the optimization problem yields a bundle of efficient portfolios, i.e. the farmer rationally restricts his choice to those farm plans for which the associated income variances are minimum for given expected income levels (Hazell and Norton 1986). Given a set of efficient farm plans the choice of a particular plan will depend on the farmer's preferences among various expected income and associated variance levels. Assuming that a utility function with a specific risk-aversion coefficient is given, a unique utility-maximizing farm plan can be rigorously identified. However, quadratic utility functions have been largely dismissed due to implied increasing absolute and relative risk aversion (Brogan and Stidham 2008, Elton and Gruber 1991, Unser 2000).

Other approaches deviate from the use of the E-V criterion and instead use target-related risk criteria with linear programming, such as the MOTAD model by Hazell (1971), the Target MOTAD by Tauer (1983) and Teague et al. (1995), or the MRCLP model by Chen and Baker (1974).

Despite the normative appeal of EU theory (von Neumann-Morgenstern), the use of utility functions to derive an optimal farm plan has been disputed due to several reasons. The main argument is that the assumption of certain risk aversion parameters is often arbitrary, and the difficulty and vagueness in the process of eliciting utility functions by use of aggregate data renders empirical applications little more than illustrative exercises (Unser 2000, Just and Pope 2003). Besides, Tew et al (1992) show that different assumptions concerning the utility function and the risk aversion parameter result in quite pronounced differences in the EU approximations. Also, Lence (2009) strongly suggests that the use of typical production data is unlikely to allow the identification of the risk-aversion structure, and that the quality of utility parameters is very poor. In a critical review of formal risk analysis models Pannell et al. (2000) argue that "for decision problems most commonly modeled by agricultural economists, the extra value of representing risk aversion is commonly very little" (p.76), and that the identification of the optimal farm plan is often of secondary importance in determining how farms are managed, since a normatively plausible theory does not inevitably lead people to apply its implications (Unser 2000).

We therefore abstain from assuming a utility function in this paper. Since the specific form of the utility function is irrelevant if returns follow a normal probability distribution, we reduce the complexity of decision by using the moments of income distributions in describing the return to assets for different activities and associated risk levels. Applying stochastic dominance rules to compare the performance of different livelihood systems yields the same result as maximizing expected utility for risk-averse households (Unser 2000). Moreover, instead of using a "typical farm" representing the type of farms found in the study region as is usually done in mathematical optimization models, income distributions are generated for individual households.

3 Methodology

Developed by Markowitz in the 1950s, the portfolio theory was particularly designed for risk analysis of financial asset portfolios. The fundamental intuition of portfolio theory is that the risk of a combination of assets is not equal to the sum of single asset risks, depending on the correlation structure of asset returns. As a measure of risk, traditional portfolio optimization uses the standard deviation or variance of returns. An overwhelming number of publications have since been devoted to the development of risk measures, the analysis of portfolio risk, and particularly to optimization problems which aim at establishing expected value-variance approximations that produce maximum or nearly maximum expected utility (Tew et al 1992).

In this paper we analyze portfolio decisions of rural households living in fishery-dependent communities by applying the general portfolio theory. For the analysis of agricultural activity portfolios the following assumptions are made:

1. Farmers behave in a rational way, i.e. productive assets are allocated among the different activities in order to maximize total utility.
2. The relative weight of each activity in the portfolio is represented by the share of assets allocated to this activity: $w_i = \sum_{a=1}^{m} \frac{x_{a,i}}{X}$, where *a* denotes the productive assets or input factors (*a* = 1,…,m), and *i* denotes the income generating activities (*i* = 1, …,n) a household is engaged in. In particular, for simplification reasons we assume labor to be the limiting factor. Income generating activities in our study region such as crop production or fishing are characterized by high labor intensity. In addition, the substitutability of capital and labor is very limited. The input factors can therefore be reduced to one single input variable, labor, and hence income of activity *i* is a function of labor input: $I_i = f(L_i)$ and $w_i = \frac{l_i}{L}$, where L is total labor available to the household, measured in mandays.
3. Labor is completely distributed among the different activities in the portfolio of a given household. $L = \sum_{i=1}^{n} w_i$.
4. We assume linear production functions for each activity, i.e. marginal productivity is constant with increasing labor input: $\frac{\partial I_i}{\partial L_i} = const > 0$ and $\frac{\partial^2 I_i}{\partial L_i^2} = 0$
5. The returns to labor for each activity are computed as the maximum possible income if all labor would be assigned to the respective activity. The portfolio income then results from the allocation of labor to the different activities.

In the analysis of agricultural risks it is important to differentiate between the concepts of uncertainty and risk. While uncertainty is typically defined as a situation where it is not possible to identify a set of events and their respective probabilities, risk is restricted to situations where the analysis of decision-making choices can be done subject to the (objective or subjective) probabilities of identifiable states of the world (Ellis 1993). Chicken and Posner (1998) state, that any definition of risk is likely to carry an element of subjectivity, depending upon the nature of the risk and to what it is applied. As such, they define risk as a function of hazard and exposure, where hazard is ‘the way in which a situation can cause harm’, and exposure is ‘the extent to which the likely recipient of the harm can be influenced by the hazard’, implying the notions of frequency and probability. Within the setting of agricultural production of rural households in developing countries, risk can hence be best captured by analyzing the impact of adverse climatic situations on farm outputs such as yield, price and income (as a combination of the two).

Hence, the stochastic distribution of returns for each activity results from yield and price variations between years with different climatic conditions. Denote $s=(1,...,S)$ the set of states of nature, and assume it is finite. Then *E(I_i)* and *V(I_i)* are functions of the probabilities γ_s, yield $Y_{i,s}$ and price $P_{i,s}$. More precisely:

$$E[I_i]=\sum_{s=1}^{S}\gamma_s\cdot Y_{i,s}\cdot P_{i,s}\ ,$$

$$V[I_i]=\sum_{s=1}^{S}\gamma_s\cdot\left(Y_{i,s}\cdot P_{i,s}-E[I_i]\right)^2\text{ , and}$$

$$Cov[I_i,I_j]=\sum_{s=1}^{S}\gamma_s\cdot\left(Y_{i,s}\cdot P_{i,s}-E[I_i]\right)\cdot\left(Y_{j,s}\cdot P_{j,s}-E[I_j]\right)\text{ for all } i\neq j\in n$$

The mean and variance of the portfolio is then:

$$E[I_{PF}]=f(\vec{w}_i,E[I_i|\gamma_s,Y_s,P_s])=\sum_{i=1}^{n}w_iE[I_i]=\sum_{k=1}^{K}\sum_{i=1}^{n}w_i\gamma_sY_sP_s$$

$$V[I_{PF}]=f(\vec{w}_i,V[I_i],Cov[I_{i,j}])=\sum_{i=1}^{n}\sum_{j=1}^{n}w_iw_j\sigma_{ij}^2$$

The two moments of the distribution of portfolio income describe the stochastic nature of production, depending on the uncertain outcomes of the single activities.

In order to compare different income portfolio compositions in terms of efficiency, we apply stochastic dominance (SD) rules. An advantage of SD is that it does not require the assumption of a specific risk-utility function. The knowledge of a concrete function is replaced by assumptions about properties of a function, thus simplifying the decision problem by sorting out dominated alternatives (Brandes and Odening 1992, Unser 2000).

As such, distribution B is said to dominate distribution A stochastically at order α if $D_A^\alpha(x)\geq D_B^\alpha(x)$ for all $x\in R$, where $D_A^\alpha(x)=\frac{1}{(\alpha-1)!}\int_0^x(x-y)^{\alpha-1}dF(y)$ (Davidson and Duclos 2000). Under the weak assumption of risk aversion SD can be embedded into general utility theory as follows (Schmid and Trede 2006, Unser 2000):

- For all $u(x) \in U_1 \equiv \{u(x) | u'(x) > 0\} \Leftrightarrow FSD\ (\alpha = 1)$
- For all $u(x) \in U_2 \equiv \{u(x) | u'(x) > 0\, and\, u''(x) < 0\} \Leftrightarrow SSD\ (\alpha = 2)$
- For all $u(x) \in U_3 \equiv \{u(x) | u'(x) > 0; u''(x) < 0\, and\, u'''(x) > 0\} \Leftrightarrow TSD\ (\alpha = 3)$.

Probability distributions of income can therefore easily be compared among each other. In particular, we can identify income portfolios that are more appropriate to cope with climate variability against other alternatives.

4 Study area and data collection

This study has been conducted in the Logone floodplain in the Far-North province of Cameroon (called *yaéres* in local language), which is located between 10°50’ and 12°10’ North latitude within the Lake Chad basin (Figure 2). In total, the floodplain covers about 8,000 km^2 and is part of the bigger Logone-Chari sub system in the Lake Chad Basin, which supplies 95% of Lake Chad's total riverine inputs and has a basin area of approximately 650,000 km^2 (UNEP 2004).

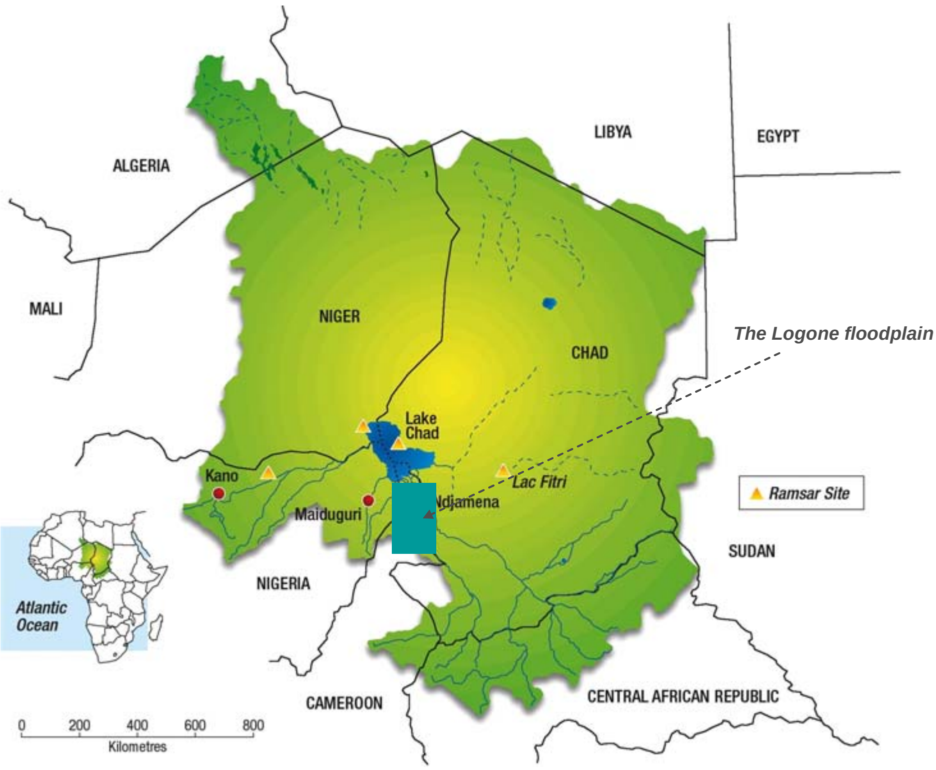


Figure 2: The Lake Chad Basin and the Logone floodplain in Cameroon
Source: WWF (2003)

Ecologically, this area is characterized by Sudano-Sahelian climate and vegetation. It is mostly covered by fluvio-lacustrine deposits which have given rise to hydromorphic sandy clays and vertisols (Ramsar wetlands). However, barren soils constitute about 30% of the surface area (Molua and Lambi 2006).

Annual average temperatures in this region vary from a minimum of 21.41 to a maximum of 34.47°C. Temperatures are highest in April (monthly average is 32.6°C) and lowest in January with 24.5°C on average (measured over the period 1961-1990, National Oceanic and Atmospheric Administration 2007). Rainfall in this area ranges between 400 and 900mmy^{-1} with a rainy season of about five months – from mid-May to mid-October. The rest of the year is marked by a pronounced dry season which persists long enough so that for at least three months most soils are dry making cropping activities impossible (Molua and Lambi 2006, Kouokam et al. 2004). The hot dry Harmattan wind blows across the floodplains during this dry season and particularly towards the north, the shortage of water is remarkable.

There is a dense hydrographic network made up of seasonal and permanent rivers which crisscross the zone. The main river in this area is the Logone which is fed mainly by tributaries from the Adamawa high plateau and the Mandara mountains, and forms the Cameroon/Chad border over a distance of 350km until it discharges into Lake Chad (Molua and Lambi 2006). During the rainy season, the Logone overflows the banks causing the annual flood regime that characterizes the *yaéres* plain. The flooding usually occurs during the peak period of rainfall in August-September. However, the pattern of flooding and the depth of the flood vary from year to year. In normal years, a large area of the plain is flooded to a depth of 1m, with maximum depths of 3m, but a series of drought in the 1970s and 80s have brought a devastating ecological imbalance in the region resulting in minimal flooding and the drying of many waterholes (Ramsar wetlands).

According to Molua and Lambi (2006) this zone is threatened by desertification as a result of low and spatially and temporally unevenly distributed rainfall, land degradation, high population pressure (2.19% population growth rate in Cameroon, CIA World Fact Book 2009), and poor management of protected areas. This process results in an increasing pressure on natural resources, the effects of which are deforestation and overfishing, among others. Human intervention through grazing and bush fires has been adding to the climatic variation. One of the man-made ecological changes in the study area has been the construction of the Maga dam on the Logone in the 1970s, which resulted in the Maga Lake with a water surface of 39,000ha. The dam was created for the establishment of two large rice irrigation schemes (SEMRY) on an area of 12,000ha. One consequence of this development is that the traditional flooding cycle has been disrupted for an area as large as 59,000ha, which lies behind a dike constructed along the left bank of the Logone to protect the irrigation project. Further, another 100,000ha outside the dyke have been ecologically affected (Ramsar wetlands). Agricultural production as well as fishing activities in the floodplain north of the Maga Lake are often subject to the control of the water flows of the Logomatya and Loromé Mazra (tributaries of the Logone) by the SEMRY.

The livelihoods of the people living in the *yaéres* (mainly subsistence agriculture and small-scale fisheries) are hence heavily dependent on natural resources and climate conditions. Due to the increasing aridification and increased frequency of droughts and floods, agricultural production in this area has been shifting to grain crops which require little rainfall and have a short growing season, such as sorghum and millet, which are hardy plants with relatively low water requirements with an annual rainfall minimum of about 500mm for sorghum and 250mm for millet. Rice is mainly cultivated in the irrigated plots of the SEMRY, but rainfed rice varieties are also grown in some parts of the floodplain. Fishing is a major activity for many households in terms of nutrient supply and income generation. It is carried out by almost every conceivable means (lines, nets and a variety of traps). In the past two decades many households have intensified fishing by digging long channels inland from the Logone and the Logomatya (up to 10km) trapping the fish that is migrating from the floodplain back to the rivers after reproduction at the end of the inundation period. Thus many juveniles are caught, increasing the pressure on the fish stock (Ramsar wetlands). Annual catch volumes in the floodplain have been estimated as low as 2,000 tonnes in the 1980s (Drijver and Marchand 1985) but have decreased since then.

A two-step weighted random sampling procedure was employed to identify the sample households. In the first step, the study region has been stratified into 3 zones with different production conditions (Figure 3): the Lake Maga area (zone 1), the Logone and its tributaries (zone 2), and the arid, only short-term flooded area (zone 3). Out of 88 villages in that area, 14 villages were selected by weighted random sampling. And finally 300 households were selected proportional to the village size. The final sample size after data entry and cleaning is 238.

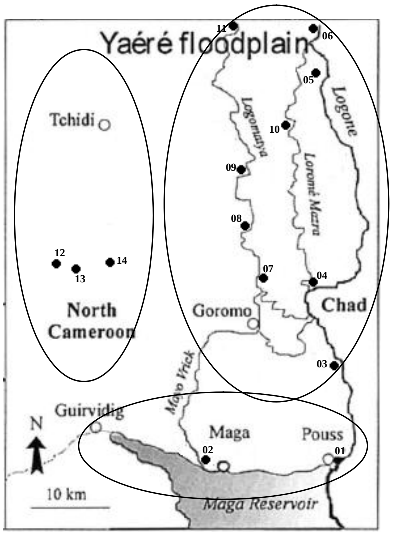


Figure 3: Map of the study area, the zones, and the 14 villages selected for the study

Source: adapted from Béné et al 2003a

For the collection of data on crop yields, prices, and income flows from fishing, we applied a visual impact method (VIM), based on Hardacker et al. (1997). VIM is an approach to elicit subjective probabilities for stochastic outcomes, as long as the number of possible outcomes is not too great. In our case we delimited the states of the world to S=3, i.e. "bad year", "normal year" and "good year". In a risk assessment interview, three rectangles were drawn on the soil, designating the three states of the world. After enquiring about the household's main income generating activity, each respondent (usually the household head) was then asked to report how often out of the past ten years (covering the period 1998-2008) they had encountered a bad, normal or good year in this primary activity. For this exercise they were given 10 stones and asked to allocate them among the three rectangles. The relative number of stones in each state of the world represents the subjective probability of facing a certain climatic event (either normal, adverse or favorable). Referring to this probability distribution, several questions followed concerning the average yield levels for the primary crop (as well as for all complementary activities carried out by the household) in each state of the world. The data that was generated through this exercise was used to derive probability density functions for each activity, as well as the correlation coefficients between the activities.

A limitation of this approach is that it is not possible to cover the tails of the yield distributions for complementary activities, since the primary activity is taken as a reference. However, in the presence of data limitations this constraint had to be accepted for the benefit of capturing the correlation structure between different activities.

The labor input data that was used for portfolio analysis has been reported in mandays for the year 2007, covering all seasons. This data has been used as an approximation for the average labor input.

5 Results

5.1 Climate risk and agricultural production

The closest meteorological station in the study area that recorded climate data over the past 30 years is Maroua-Salak (10.4°N, 14.2°E, 423m), which can be taken as the southern border of the Logone floodplain. Data on rainfall (Figure 4) show that total annual precipitation volumes vary considerably from year to year. The average negative deviation from the historical mean of 805.33 mm y^{-1} is -105.3 percent and the average positive deviation is 120.9 percent. In the 1980s Cameroon faced a prolonged drought with rainfall as low as 487.4 mmy^{-1}, and shorter, less pronounced droughts in 1996-98 and 2004-06. Abrupt changes in rainfall are however a general phenomenon for this area (e.g. 1993-94 or 2006-07), which may contribute to a high variation of outputs from agricultural production and fishing activities.

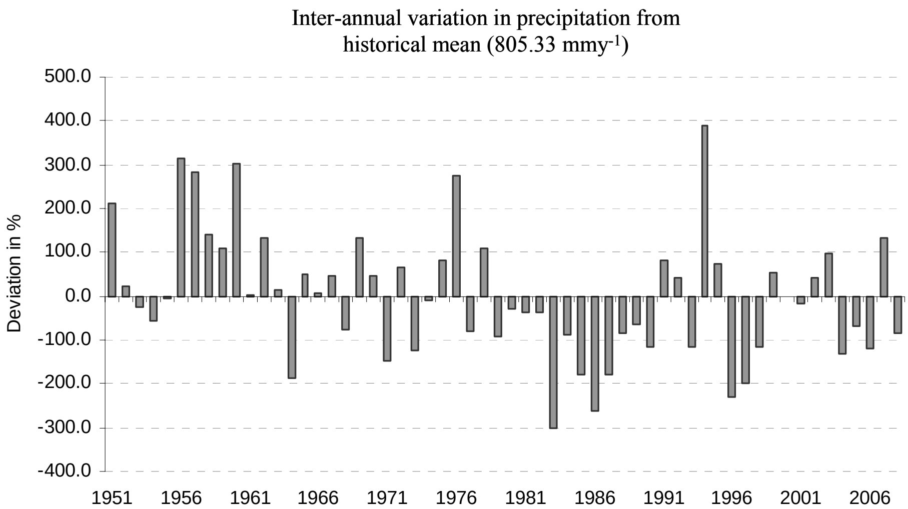


Figure 4: Evolution of annual rainfall in the study area

Source: Direction de la Météorologie Nationale du Cameroun: Service Régional de la Météorologie de l'Extrème Nord

In addition, the uncertain nature of climate is manifested not only in the total annual rainfall values but also in the irregularity of rainfall within the year, which is an important factor for outcomes of agricultural production. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops (Ellis 1993, Molua and Lambi 2006, McCarl et al. 2008). Figure 5 shows exemplarily the evolution of rainfall for two years, 1984 and 1986. In 1986 total annual precipitation was lower than in 1984. However, in 1984 rainfall was abundant only during the planting season in Mai, but failed to arrive in the crucial growing period in June. Production data from Cameroon show that e.g. sorghum and millet yields decreased by up to 40 percent below average[1] in that year, while in 1986 sorghum yields were at 59 percent above average.

Such adverse climate effects are supposed to be reflected in farmers' perceptions of favorable or unfavorable years concerning agricultural activities and fishing. On average, farmers reported subjective probabilities of facing a bad, normal or good year of 38, 34 and 28 percent, respectively. The probabilities were elicited with respect to the primary crop. No significant difference regarding probabilities of states of the world can be observed between different farming systems, showing that risk perception is consistent among the population, and that the exposure to natural hazards is overall comparable between different livelihood systems.

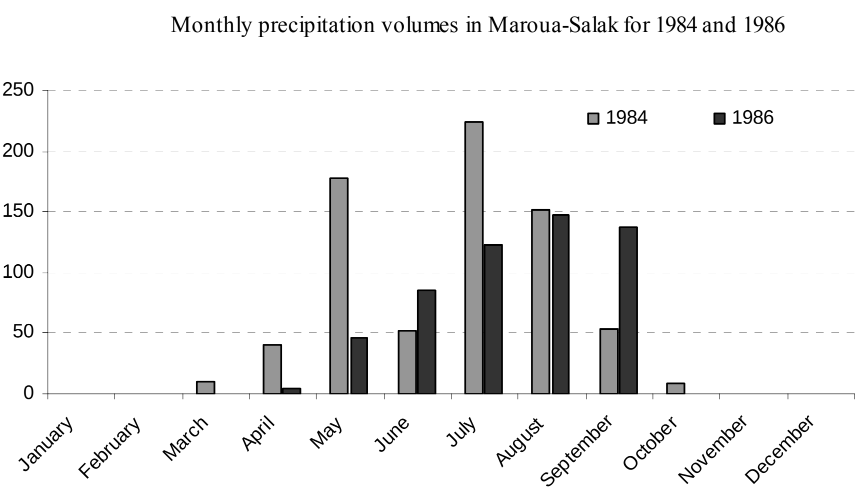
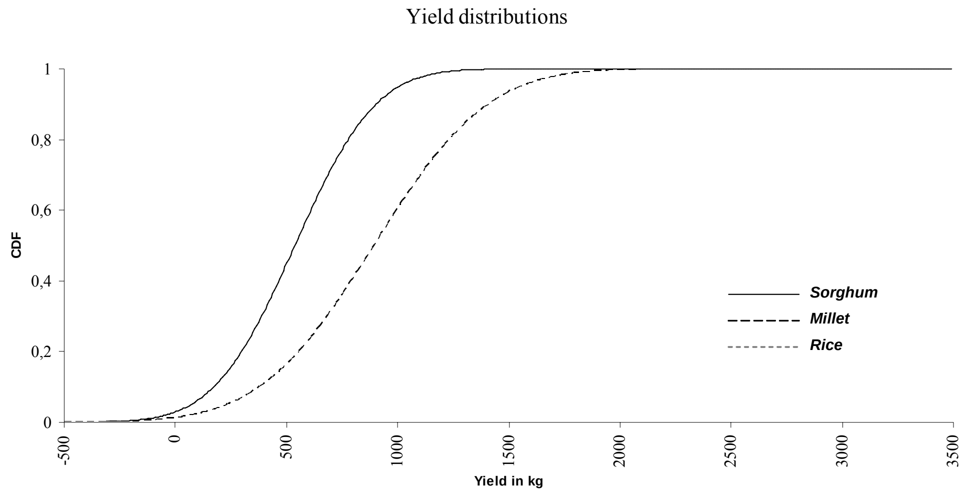


Figure 5: Evolution of intra-annual rainfall in the study area for 1984 and 1986
Source: Direction de la Météorologie Nationale du Cameroun: Service Régional de la Météorologie de l'Extrème Nord

[1] Historical average was calculated based on yield data from 1961 to 2005 (FAOSTAT)

Production risk, as a function of hazard and exposure, is reflected in the stochastic distribution of yield levels[2]. Figure 6 shows the cumulative density functions for sorghum, millet and rice yields and prices over the period of 10 years, based on data from the risk assessment exercise[3], as well as the income distributions. In general, the analysis of yield distributions confirms empirical findings that higher output is often associated with higher risk. Average yield is lowest for sorghum with 526kgy^{-1} (sd = 272) and highest for rice with 1712 kgy^{-1} (sd = 650). In terms of yields, rice is clearly dominating millet and sorghum by first-order stochastic dominance.



[2] Concerning fishing catch levels, it turned out to be impossible to collect reliable recall data on the quantity of fish production due to the large diversity of fish species, fish sizes and catchment levels varying from day to day. Farmers however could report the revenues from fishing, which have been incorporated into the analysis of portfolio income.

[3] The analysis of baseline data reveals that these four activities are the major income sources for households in the Logone floodplain. Other crops such as maize or green beans compose less then one per cent of total income. Also, off-farm work possibilities are limited and carried out by only 11% of all households with an average contribution to household income of 1.5 percent. For the analysis of production systems these activities are therefore considered as insignificant.

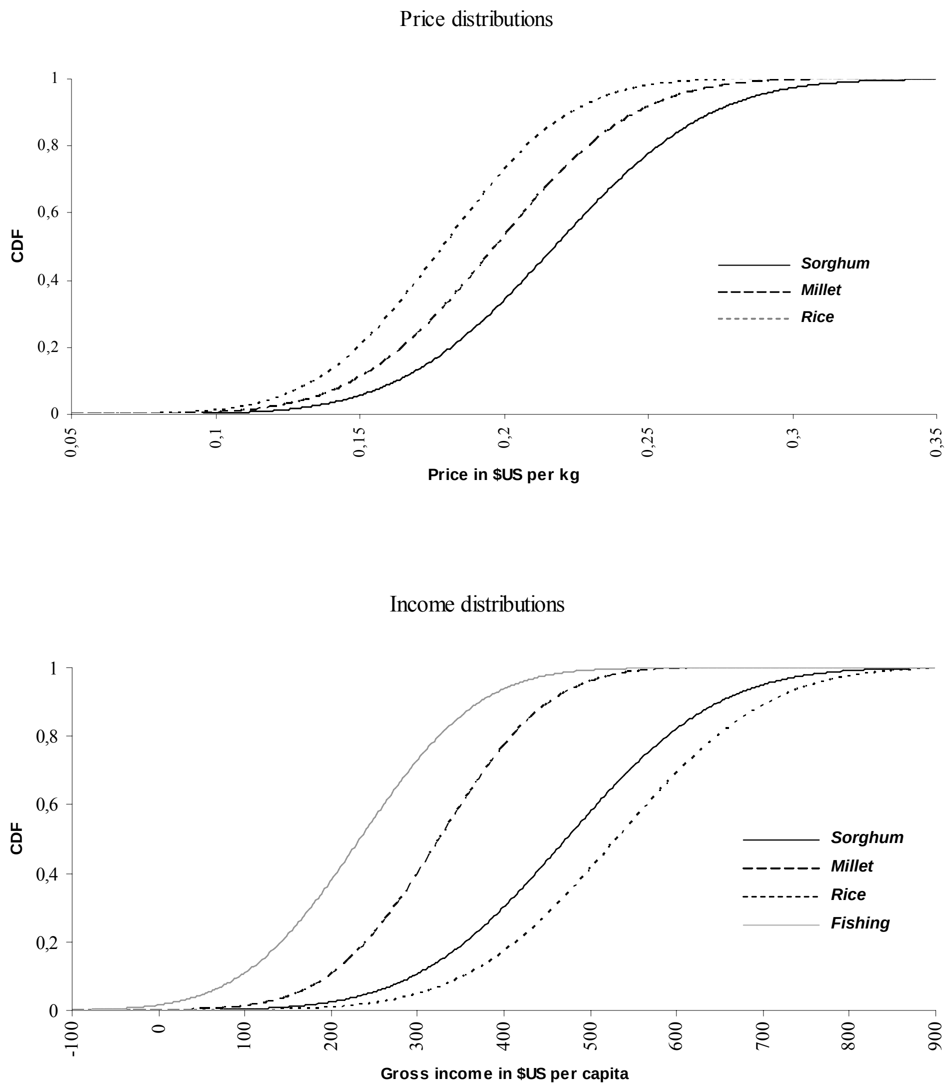


Figure 6: Cumulative distribution curves of average yield levels for the major crops
Source: own illustration

Since the price for the major agricultural commodities - sorghum, millet and rice - is a function of supply and demand, a considerable variation in price can be expected due to a supply shortage in bad years and an oversupply in good years. The variation of price is therefore depending on aggregate supply and demand, and hence on the sensitivity of crop yields to climate variations. Overall, it can be observed that prices for all three crops have comparable distributions, although prices for sorghum are highest and display the lowest variation, while rice is the cheapest cereal with the highest variation in price. The reverse order of stochastic dominance between prices and yields suggests that the variation in yield is partly compensated by inversely proportional variation in prices (negative correlation between yield and price), which is in harmony with economic theory. Despite the countervailing effect of prices on the stochasticity of yield levels, the value product, measured as gross income per capita, shows that incomes from cropping and fishing are also highly stochastic. By first-order stochastic dominance, rice is dominating other crops, while fishing income is being dominated by farming activities.

Nevertheless, the question remains, how combinations of different activities in a specific portfolio may contribute to risk reduction or utility maximization of rural households.

Diversification of production as a risk-management strategy can only be pursued in the space of possible activities. Chaplin (2000) notes that there might be multiple reasons for varying levels of specialization and diversification one of which is the availability of resources (i.e. soil type, local climate, water availability, etc.) that affect the opportunities of income diversification. The income distributions displayed in Figure 6 compose the space of possible diversification decisions for households in the study region. Distributing labor among the possible activities results in a portfolio income and associated risk, measured by the standard deviation of income. Portfolio theory suggests that substantial risk-mitigating effects can be achieved by combining activities with low correlation of returns. However, the strong dependence on seasonal rainfall patterns in the study area implies a low diversification effect (Table 1). A low rainfall level not only means that crop yields are threatened, it also results in low water levels in the water bodies which affects the reproduction of fish during the inundation period, and therefore reduces fish catch volumes and income for farmers.

Table 1: Pearson correlation coefficients for income between activities

	Sorghum	Millet	Rice	Fishing
Sorghum	1.00	0.74	0.86	0.93
Millet		1.00	0.91	0.87
Rice			1.00	0.85
Fishing				1.00

Source: own data

Nonetheless, farmers are observed to diversify their income portfolio. Table 2 shows the share of labor allocated to the primary activity, the average portfolio income, the average standard deviation of income, the average number of activities, and the Simpson Index of Diversity

(SID)[4]. Total portfolio income is derived by combining the moments of the distribution of single activities, weighted by the labor share allocated to the respective activity. The mean and variance of portfolio income now not only depend on the distribution characteristics of income from each activity but particularly on the specific combination of activities. The diversification effect, as suggested by portfolio theory, is expected to be low due to high correlation coefficients. Nonetheless, we hypothesize that differences in labor allocation might significantly affect household income and risk liability. For simplification and comparison reasons, we classified households into four livelihood systems, considering the activity with the highest labor allocation as the primary activity (although there is a multitude of possible combinations of the four activities, sorghum, millet, rice and fishing, and the specific portfolios are different for every household). Hence households were classified as (1) Sorghum growers, (2) Millet growers, (3) Rice growers, and (4) Fishermen.

Table 2: Diversification indicators by livelihood group

	Sorghum growers	Millet growers	Rice growers	Fishermen
N	91	27	90	30
Percent of sample	0.382	0.113	0.378	0.126
Average labor allocation to primary activity (in percent of total labor)	0.491	0.365	0.532	0.319
Mean portfolio income (in $US)	408.1	276.0	247.7	579.4
SD of income	151.4	69.7	54.3	176.1
No of activities	1.96	2.56	2.10	2.77
SID	0.66	0.78	0.62	0.82

Source: own data

Income distributions for these four livelihood groups show the following order by second-degree stochastic dominance: Fishermen $\succ$ Sorghum growers $\succ$ Millet growers $\succ$ Rice growers. This result shows that despite the fact that income from fishing was clearly dominated by rice (see Figure 6), fishermen excel in the overall portfolio income distribution by combining fishing with other activities. This indicates that livelihood choices may have an impact on risk liability.

4 The SID is computed as: $1-\sum_i {w_i}^2$, where w_i is the labor share allocated to activity *i*.

5.2 *Scenario analysis*

In order to test, how certain hypothetical interventions would affect income and risk, a scenario analysis has been conducted based on research findings and policy propositions.

Following forecasts on climate change it can be assumed that extreme events, such as flooding and drought will occur more often in the future. As exemplified by McCarl et al. (2008) higher variance in climate conditions tends to lower average crop yield and increase the variability of crop yield distributions. In combination with ongoing aridification and desertification of the study area, we can presume that the probabilities of extreme events will increase in the future. To simulate such changes on the portfolio outcomes, we assume a shift of probabilities from a "normal" year to "good" and "bad" years in our subjective probabilities distribution by 50% respectively. The first scenario therefore shows the trend in income and risk changes due to climate change.

Addressing climate risks, autonomous adaptation strategies, such as changing crop varieties, altering the timing or location of cropping activities, or diversification, are highly relevant for smallholder farmers (IFAD 2008). Certainly, in the context of agricultural production under water stress and increasing climate variability, a promising adaptation method is improved crop and soil water management (Giorgis et al. 2006, Molua 2008). According to Ellis (1993), perhaps the most obvious policy response to natural uncertainty is that of irrigation as an answer to rainfall variability, which may not only alleviate the risk of drought but also smooth out within-season fluctuations of water supply. A number of qualitative and quantitative studies have shown that irrigation is an effective means to countervail the adverse effects of climate variability, such as loss of rainfall and high temperatures (e.g. Molua 2008, Hassan and Nhemachena 2008, Carsky et al. 1995). Kurukulasuriya and Mendelsohn (2006), for example, examine how climate affects the net revenues of dryland and irrigated land controlling for the endogeneity of irrigation. They find that precipitation has virtually no effect on the net revenues of irrigated farms, implying that irrigation serves as a buffer against rainfall variation. Similar findings are provided by Kurukulasuriya and Mendelsohn (2008). A trial experiment in the Maroua-Salak region by Carsky et al. (1995) demonstrated that the response of dry season sorghum to supplemental irrigation is substantial with up to 60 percent yield increases. They therefore suggest that research should focus on improvements in soil moisture availability. For the second scenario we therefore test the effects of a project on improved irrigation in sorghum production as a model case for other similar development projects. Based on Carsky et al. (1995) we assume a 55% increase in sorghum yields in bad years by improved soil moisture. Apart from the income-increasing effect such an improvement in sorghum cultivation would also most certainly result in lower correlation of sorghum yields with other crops.

Another proposition to address the problem of poverty and vulnerability is to provide additional income for the poor through diversification in fish production (CGIAR 2005). However, a major obstacle to risk-reduction via diversification is the almost perfect correlation of crops and fishing activities for our sample population. If the dependency of fishers on climatic conditions such as rainfall could be alleviated, income variation from fishing could be disconnected from the variation in agricultural income. This effect is assumed to be best achieved through aquaculture and bringing new small bodies of freshwater into fish production (CGIAR 2005). Similar to the effect of irrigation, which smoothes crop yields, fish production through aquaculture is assumed to significantly reduce the dependence on rainfall and reproduction rates of the fish stock in the Maga Lake, the Logone and its tributaries, and would hence particularly address the problem of high correlation of income. Since making assumptions concerning the income-increasing effect of an aquaculture project would be elusive, we simply estimate the risk-reducing effect of decreasing covariation between fish and crop production by setting the correlation factor to zero. The results of the scenario analysis are presented in Table 3.

Table 3. Mean and standard deviation of portfolio income for different scenarios

		Sorghum growers	Millet growers	Rice growers	Fishermen
N		91	27	90	30
Percent of sample		0.382	0.113	0.378	0.126
SID		0.66	0.78	0.62	0.82
Mean and standard deviation of income					
Original scenario	Mean	408.1	276.0	247.7	579.4
	SD	151.4	69.7	54.3	176.1
Extreme events scenario	Mean	431.6***	280.9	246.9	605.6
	SD	186.6***	82.1***	65.1***	214.5***
Sorghum increases scenario	Mean	443.79***	276.25	248.62**	584.37***
	SD	132.37***	69.53	53.66**	172.79***
Aquaculture project scenario	Mean	408.1	276.0	247.7	579.4
	SD	150.0**	64.4***	50.6***	155.6***
Change in percent (relative to the original scenario)					
Extreme events scenario	Mean	5.77	1.75	-0.34	4.53
	SD	23.24	17.84	20.04	21.78
Sorghum increases scenario	Mean	8.75	0.08	0.37	0.86
	SD	-12.57	-0.18	-1.10	-1.88
Aquaculture project scenario	Mean	0.00	0.00	0.00	0.00
	SD	-0.91	-7.58	-6.75	-11.63

Source: own data

Note: *, **, *** indicate significance levels of difference in mean at 0.1, 0.5 and 0.01, respectively (T-test)

In general the findings show significant differences in mean and standard deviation between intervention scenarios and the original scenario. Under the extreme events scenario, where we assume a more frequent occurrence of good and bad years as compared to an average year, risk (i.e. the variation in portfolio income) is increasing for all livelihood groups by up to 23 percent. While slight income increases can be realized under this scenario, the difference is non-significant except for sorghum growers. As for the sorghum irrigation scenario, the results show sorghum growers may potentially profit from improved soil moisture. Under this scenario an income increase of about 9 percent and at the same time a 12.6 percent decrease in variation of income may contribute to improved livelihoods of this group. The effects for other livelihood groups are comparatively small since sorghum makes up only a small fraction of income for these households. For the aquaculture project scenario the result confirm the hypothesis, that decreasing correlation of income flows from fishing and agriculture may result in lower risk. For all groups, but especially for fishermen, income risk would be significantly reduced by such an intervention. Of course, the feasibility and economic efficiency of aquaculture projects in Cameroon need to be evaluated and debated, which is however out of scope of this paper.

6 Conclusions

Small-scale farmers in Sub-Saharan Africa often have a low adaptive capacity due to dependence on natural resources, constraints in human and physical capital, and poor infrastructure (Shewmake 2008). Repeatedly, some authors therefore express the need of governmental support in the adaptation process of small-scale farmers (e.g. Giorgis et al. 2006, Molua and Lambi 2006b, Molua 2008, Hassan and Nhemachena 2008, Deressa et al. 2009). As such, higher agricultural diversification, improved crop patterns, the cultivation of crops with lower water requirements, and improved irrigation mechanisms are supposed to ease water constraints and enhance productivity. The objective of this paper was the identification of the effect of climate variability on livelihood systems as well as the potential impact of certain policy interventions on income and risk. Susceptibility to climate risk is supposed to vary between different livelihood systems, and projects targeting at the reduction of poverty and vulnerability may need to consider the effects that these will have on different sub-populations.

We applied the general portfolio theory to the analysis of income risk for 238 rural households in the *yaéres*, one of the major floodplains in Cameroon. The results show that farmers often face a large variation in incomes due to climate risk despite agricultural diversification into crops and/or fishing. As in many similar settings, the reason is found to be a high covariation of crop and fishing incomes. It can be concluded that for subsistence households living in remote areas diversification across crops is less likely to be an effective strategy to risk reduction. In a study on coping and adapting strategies to climate variability of Bolivian rural families, Valdivia et al. (2003) conclude that indigenous knowledge on climate and the ability to make forecasts can even be undermined as a result of income diversification. It has also been argued that agricultural diversification is pursued by rural households not as a risk management strategy but rather due to economies of scope and/or to satisfy own demand for diversity in consumption (Barrett et al. 2001, Omamo 1998).

Concerning policy implications, our sensitivity analysis suggests that climate change, i.e. increasing frequency of extreme events, will worsen the situation of high production risk for the surveyed households. However, we show that development intervention strategies, which particularly aim at changing the covariation structure of income flows, are most successful in reducing risk, and potentially increasing income. This is in line with other findings. For example, Ito and Kurosaki (2009), show that off-farm employment is used by Indian farmers to stabilize income in the face of production risk. They therefore recommend policy interventions to promote sectors whose wages are less correlated with farm production shocks. Literature suggests that off-farm employment is an adequate diversification strategy, since it shows little or no price correlation between activities thereby stabilizing the variability in agricultural income (Barlett 1991, Kimhi and Bollmann 1999). Despite the theoretical attractiveness of such diversification strategies, implementing off-farm labor in our analysis proved not to be possible, since off-farm activities are extremely limited for the households in the surveyed area. However, irrigation projects show a promising effect on income and risk reduction. We argue that small-scale irrigation projects are of a more sustainable nature since large-scale irrigation projects as the SEMRY have proven to be damaging to the ecosystem and to the livelihoods of the people in the *yaéres* floodplain.

Future research should expand the analysis of income portfolios under risk by use of more sophisticated measures of downside risk. Taking the common notion of risk as a negative, undesired characteristic of an alternative in account, the analysis of income distributions needs to go beyond a mean-variance analysis, as suggested by e.g. Brogan and Stidham

(2005), Albrecht and Maurer (2002), Unser (2000), Cheng et al. (2004), and Di Falco and Chavas (2009). In particular, measures of vulnerability to poverty could be combined with portfolio analysis instruments, which may further improve the policy implications drawn in this study.

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